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Broadband VHF (B-VHF) Project Achievements And Follow-on Activities

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Overview

- **B-VHF System**
- **Transition Aspects and Migration Scenarios**
- **Achievements**
- **Introduction – From B-VHF to B-AMC**
- **B-AMC Operations**
- **High Level B-AMC Design**
- **Conclusions**

B-VHF System (1) - Main B-VHF Facts

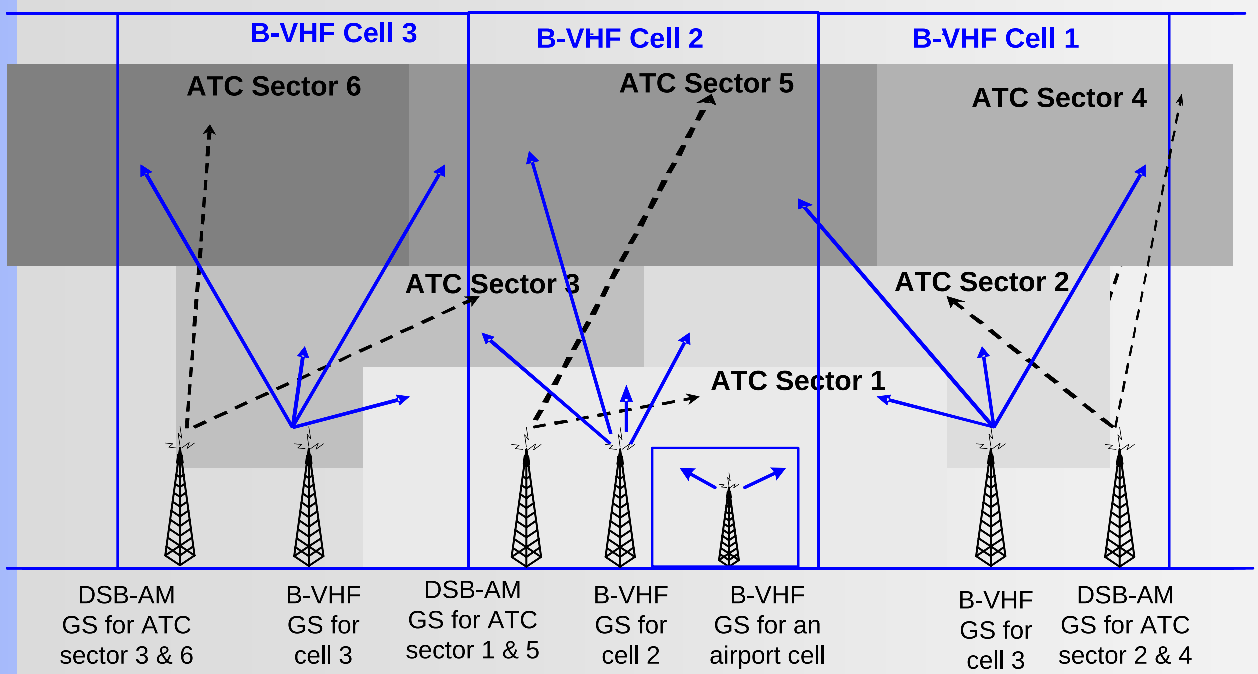
- Multi-application broadband cellular system based on multi-carrier technology
  - MC-CDMA for forward link (G/A)
  - OFDMA for reverse link (A/G)
- High capacity/high performance integrated voice and data link system tailored for specific aeronautical needs
  - Supporting existing and emerging applications and services
- OFDM and MC-CDMA are mature technologies
  - Proven by high-capacity bandwidth-efficient techniques, like DAB, DVB-T or W-LAN
  - COTS products are already available (MC-CDMA adopted proposal for 4G)
- Most modern and spectrum efficient technology

B-VHF System (2) - Communication Concept

Cellular Concept

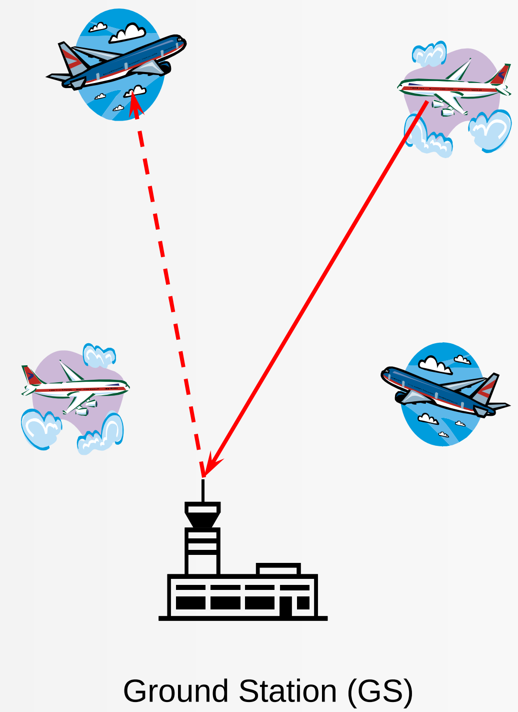
•One B-VHF cell might provide coverage for several ATC sectors

•One ATC sector might belong to several B-VHF cells



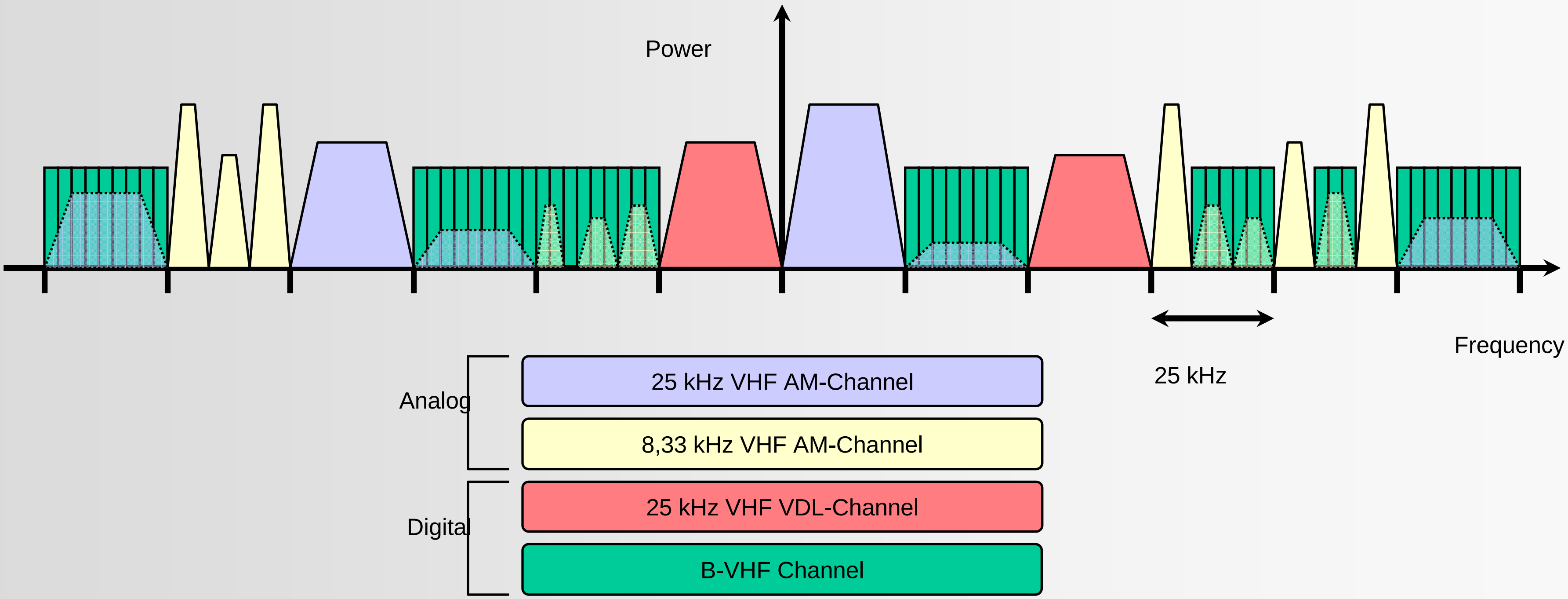
Ground station supported communications

Air-Air Communication (Voice+Data) via GS Retransmission



B-VHF System (3) - Main B-VHF Facts

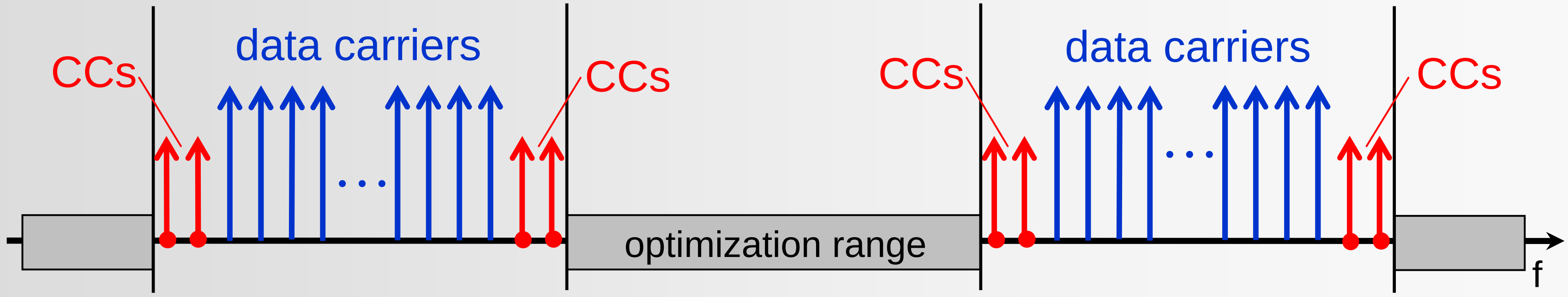
- B-VHF is primarily designed to use it as overlay system



- Overlay concept enables in-band transition (e.g. VHF band)

NBI and Sidelobe Suppression Techniques

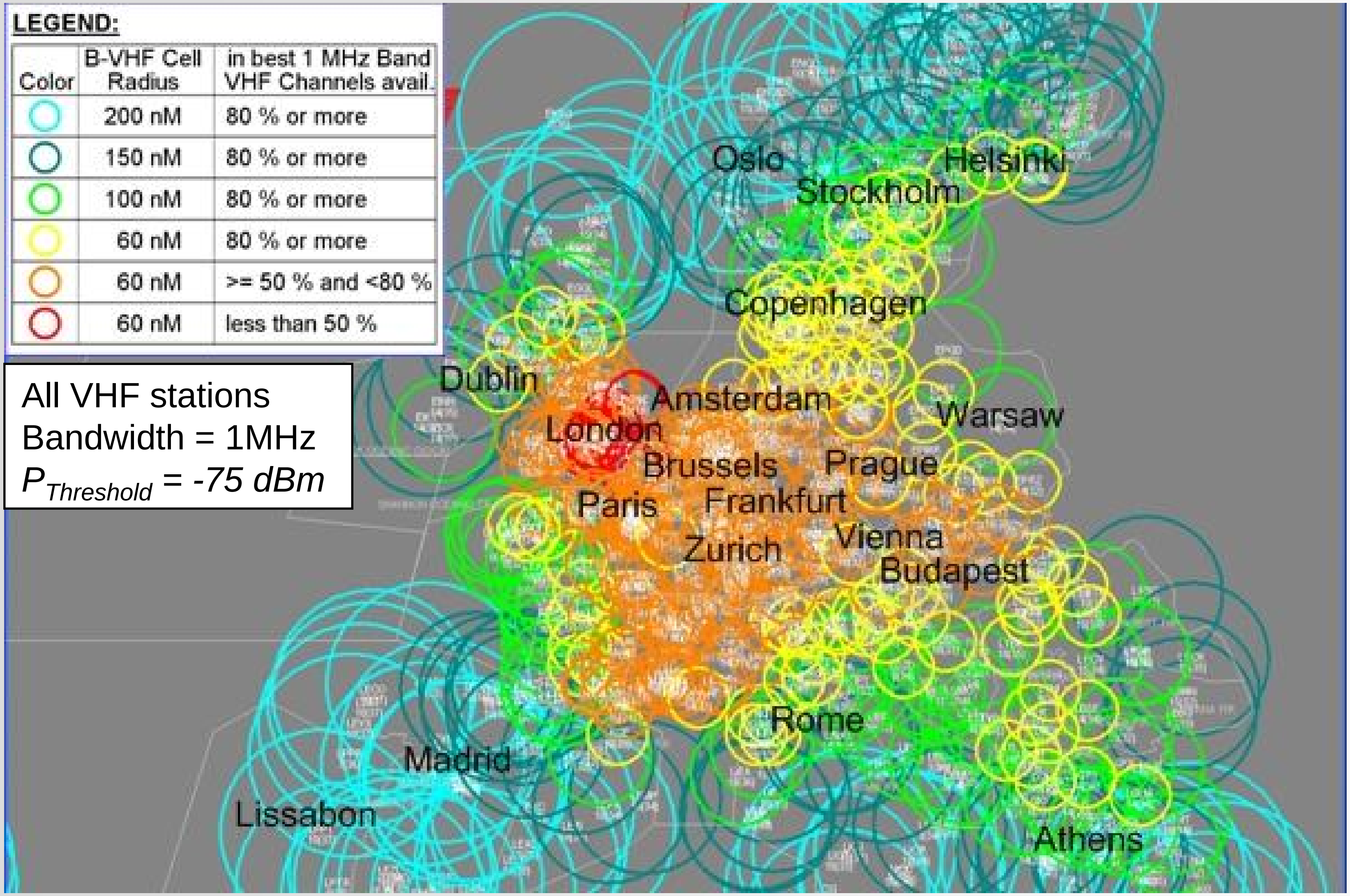
- NBI Techniques:
  - Digital notch filtering – only for strong interferer
    - Assumption: A/D converter with sufficient resolution
  - Rx windowing in time domain
    - Slight extension of time domain signal required
    - Peak of interferer is not reduced
  - Leakage compensation in frequency domain
    - Leakage effect due to DFT operation
    - Estimation and compensation of interference - Requires observation subcarrier
- Sidelobe suppression techniques:
  - Objective: Minimization of interference towards legacy VHF systems
  - Tx windowing
  - Cancellation carriers



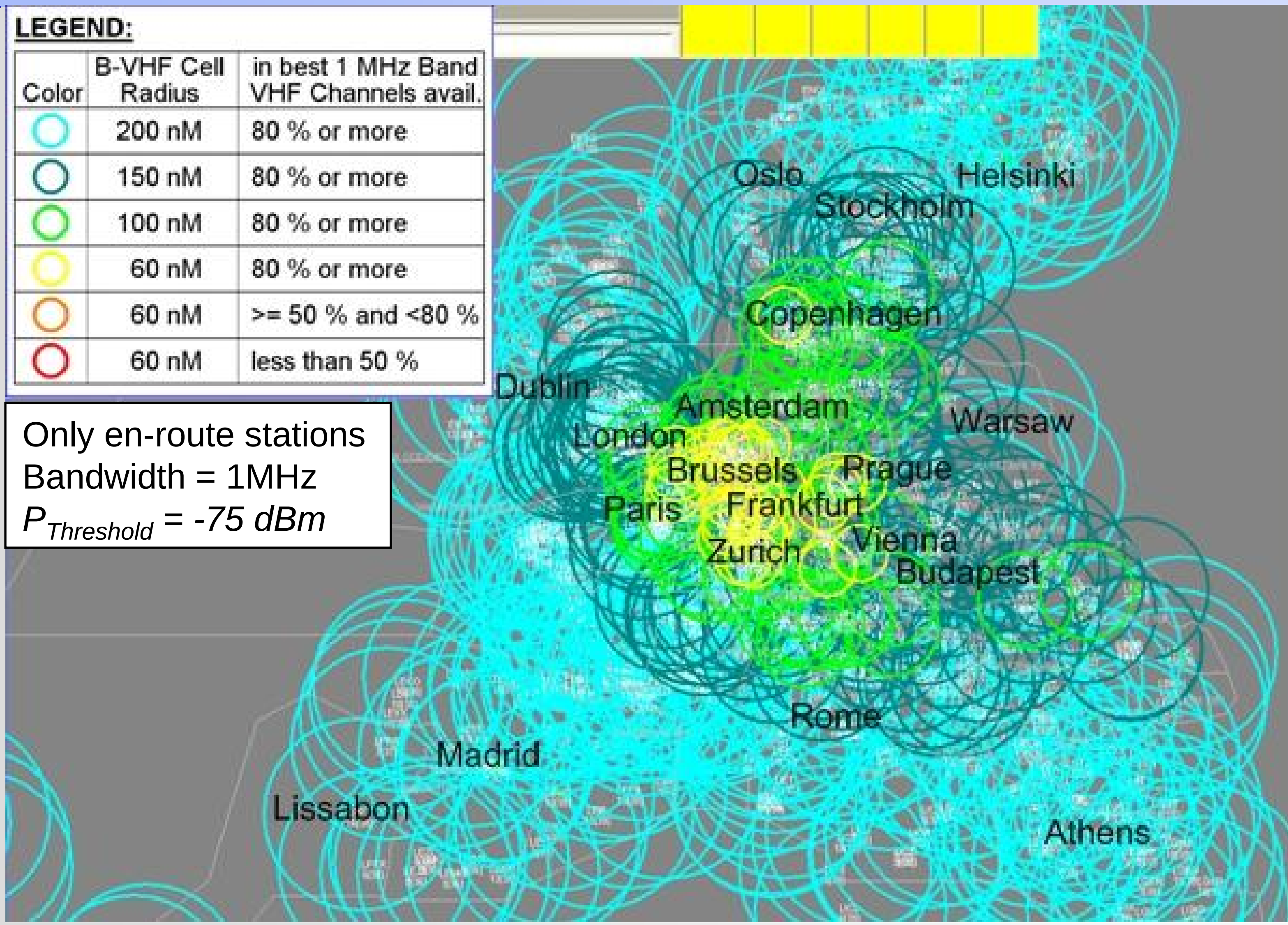
Transition Aspects and Migration Scenarios

- Aeronautical bands for a future aeronautical communications system
  - **VHF COM range** (118–137 MHz)
  - **VOR range** (target range: 116–118 MHz)
  - **DME range** (target range: 960–1024 MHz)
  - **MLS range** (target range: 5091–5150 MHz)
- Deployment mode of the airspace
  - **B-VHF-supported airspace:** B-VHF equipment is voluntary
  - **B-VHF airspace:** B-VHF infrastructure is mandatory:
  - **NB airspace**: no B-VHF system is deployed
- VHF-COM Transition: B-VHF System Deployment in the VHF COM band
  - deployment scenario is based on overlay
  - Minor adaptations on the existing system
- DME Transition: B-VHF System Deployment in the DME band
  - Deployment of a data only system in the L-band
- VHF-Transition: B-VHF System Deployment in the VHF NAV & COM band
  - partly overlay character

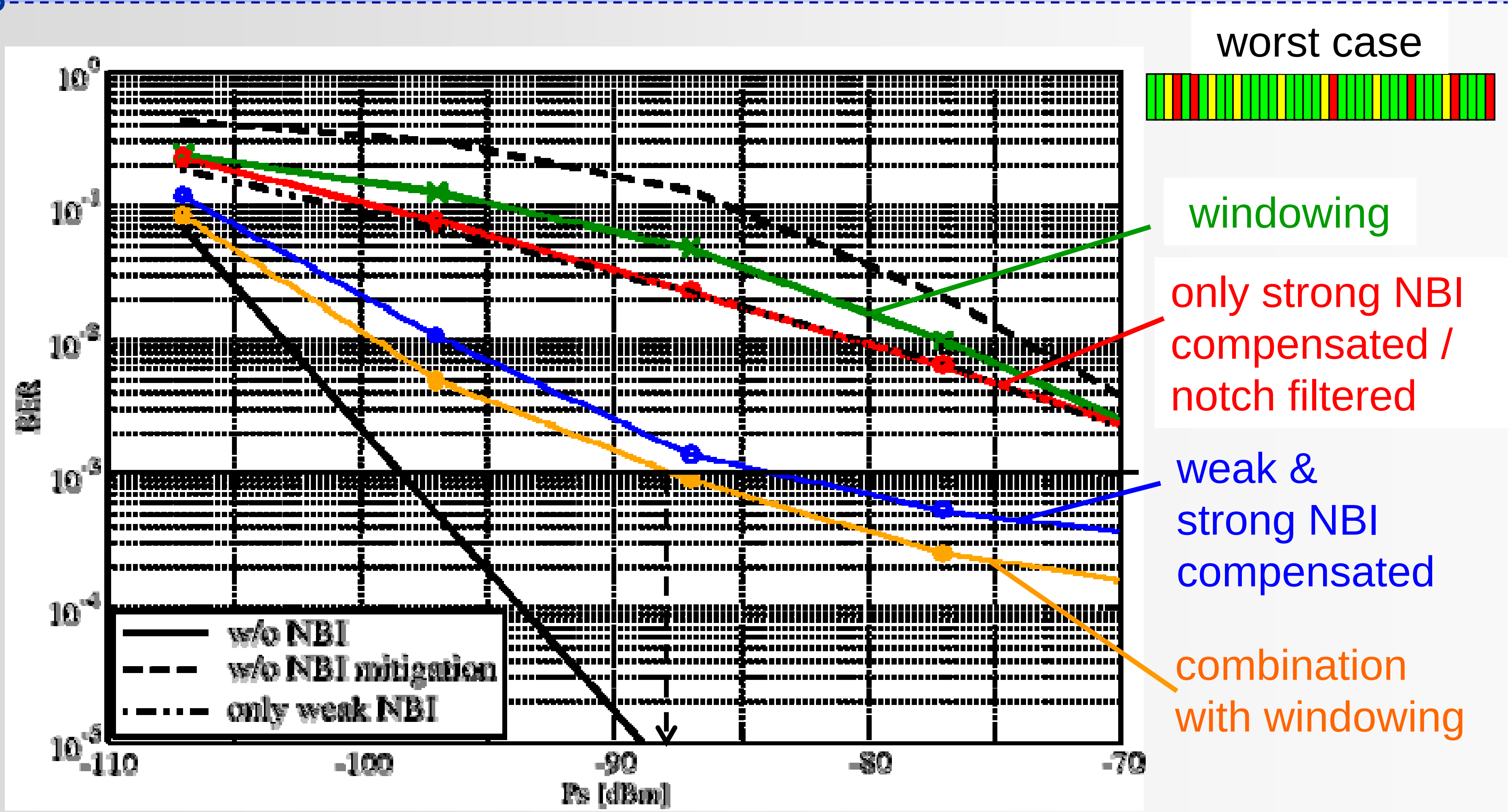
Cell Assignment for -75dBm with all VHF stations



Cell Assignment for -75dBm with en-route stations



BER Performance – ENR-WC Scenario



required Rx power: -88 dBm

Conclusions

- **Overlay concept and VHF in-band transition feasible**
  - Theoretical considerations and simulations
  - Reduced capacity during deployment
- **Multi-application System**
  - operational service coverage is independent from the physical line-of-sight conditions
  - Integrated system design supports necessary QoS for all safety-related voice and data link services for ATS and AOC.
- **Applicability in non-VHF bands with or without overlay**
  - e.g DME band for ground-based aeronautical communications
- **Scalability of B-VHF**
  - B-VHF easily scalable (data rate/capacity ~ bandwidth)
  - Large bandwidth enables high rate/capacity aeronautical communications for additional/new applications

Introduction – From B-VHF to B-AMC

- What is B-AMC?
  - B-AMC: Broadband Aeronautical Multi-carrier Communications
  - B-AMC is B-VHF adjusted to L-band use
  - Preferable B-AMC deployment between L-band DME channels
    - B-AMC is more an “inlay” than a real overlay system
    - B-AMC deployment:
      - Without considering DME frequency planning (preferred)
      - Aligned with DME frequency planning (second choice)
      - Fall back solution: “green” L-band spectrum
- Why B-AMC?
  - New data link system for 2020 shall be implemented in L-band
  - B-VHF design can be re-used for B-AMC to a large extend
    - For A/G communications B-AMC is based on B-VHF protocol concepts
    - For A/A communications B-AMC extends B-VHF capabilities
  - B-AMC allows systematic adjustments to L-band use

B-AMC Operations

- Functional Scope of B-AMC Operations
  - A/G mode – B-AMC inherits B-VHF capabilities
    - Centralized communication controlled by GS
    - Cellular communications concept with B-AMC cells decoupled from service operational coverage
    - Seamless service area and cell handover
    - Supports Data and Voice communications
    - B-AMC covers all A/G ATS and AOC services
  - A/A mode – B-AMC extends B-VHF capabilities
    - Decentralized (self-organized) direct A/A communication
    - "Communication bubbles" defined by radio range around aircraft
    - All A/A communications are based on broadcast transmissions
    - B-AMC supports A/A surveillance data link (ADS-B)
    - B-AMC covers all A/A ATS services
  - Only one mode of operation at a time is supported per radio

Required Adjustments for L-Band Use

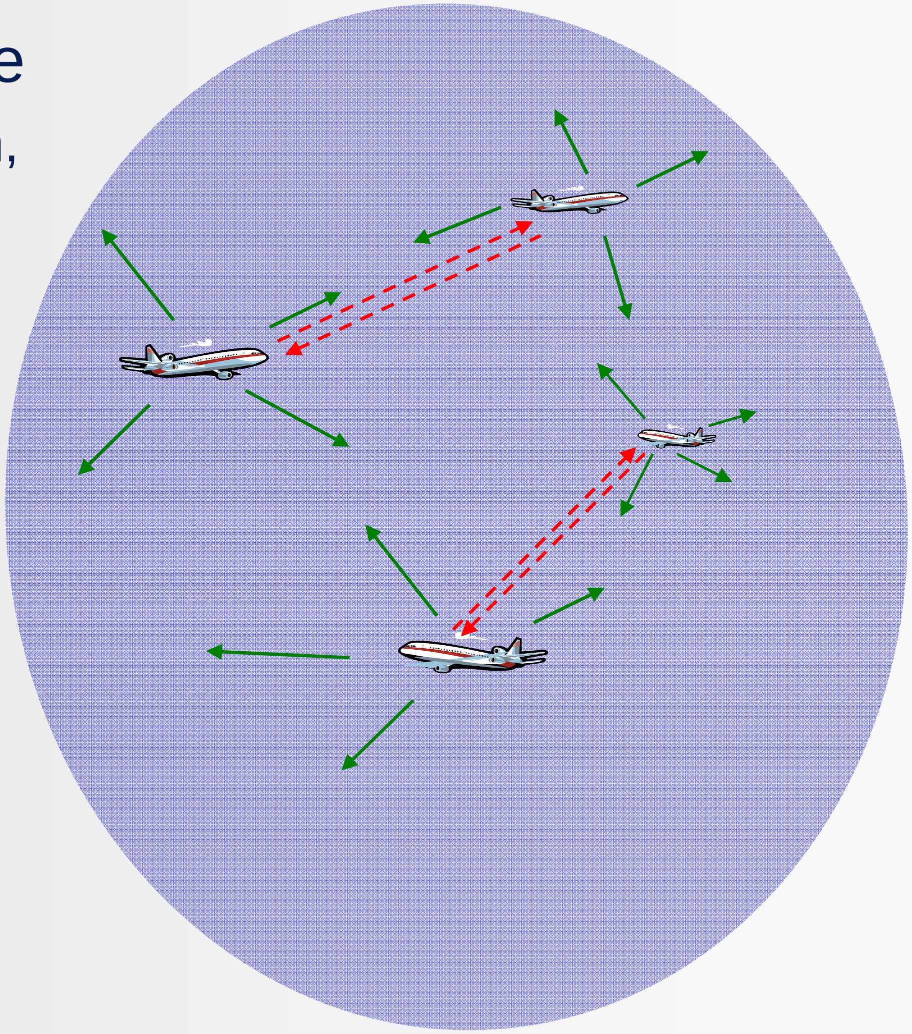
- Special L-Band Conditions
  - Interference situation and available spectrum blocks
  - High carrier frequency (attenuation, Doppler, …)
  - L-band system shall provide data communications (voice only as option)
- Required Adjustments (B-VHF to B-AMC)
  - Duplex scheme for A/G communication
    - FDD instead of TDD - Avoids large guard times
    - Use the small available channel bandwidth between DME channels
    - Relieves co-location interference situation at aircraft
  - FL access-scheme
    - OFDMA instead of MC-CDMA
  - OFDM parameters
    - Different frequency band and different interference situation
    - RF bandwidth and sub-carrier spacing have to be adjusted
  - Framing structure
    - Framing structure has to be adjusted due to FDD and adjusted OFDM parameters

High Level B-AMC Design – A/G

- Duplex Scheme and Frequency Spectrum
  - A/G communication applies FDD
  - Proposed L-band usage
    - B-AMC channel center frequencies chosen exactly between DME channel assignments
    - RL from 1040 to 1140 MHz
    - FL from 980 to 1020 MHz
  - For operation over landmass areas A/A communication in parallel to A/G communication is available
    - Complete A/A connectivity (second radio)
    - Globally available CCC
    - Proposed L-band frequency
      - CCC @ 968 MHz

High Level B-AMC Design – A/A

- Communication Architecture
  - Decentralized communication, self-organized
  - Communication bubbles defined by radio range
  - Main communications means for surveillance and A/A data link communications: **CCC**
  - Additionally (future): High-speed point-to-point link using FDD, e.g. for ad-hoc net communication



High Level B-AMC Design – A/A

- Access-Scheme and Frequency Spectrum
  - Global time reference assumed available
  - A/A communication applies self-organized OFDM/TDMA
  - Proposed L-band usage
    - CCC @ 968 MHz (2,6 MHz for ENR)
    - Additional CCCs around 968 MHz (1,3 MHz for TMA and APT)
    - High-speed point-to-point links (for future use, e.g. ad-hoc nets)
      - Re-use DME spectrum (978 – 1140 MHz) in OPR areas
      - Re-use A/G FDD B-AMC radio with extended bandwidth
      - Pure OFDM with large bandwidth (>1 MHz)
      - Higher modulation schemes, directional antennas, and MIMO
      - Extremely high data rates

High Level B-AMC Design

- Conclusions
  - Proposal for A/G high level B-AMC design
    - B-AMC covers all A/G ATS and AOC services
    - B-AMC supports A/G multi-link and multi-service communications
    - Robust PHY layer tailored to combat L-band interference
    - Efficient side-lobe suppression to guarantee co-existence
    - Optimized design for data link, but voice remains an option
    - Minimized delays due to signaling frames
  - Proposal for A/A high level B-AMC design
    - B-AMC covers all A/A ATS services
    - B-AMC supports A/A data link communication
    - B-AMC supports A/A surveillance (ADS-B)
    - Future option: High-speed point-to-point links (ad-hoc nets)

Thank you for your attention!

Any Questions?